Evaluating Gardona and Malathion To Protect Wheat In Small Bins Against Stored-Grain Insects

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PREFACE

This report presents results of a small-bin, intermediate-type experiment with wheat protectants. The treatments studied were low-volume (LV) spray and drip-on applications of malathion, an ultra-low volume (ULV) application of a chemically active insecticide, Gardona, and a formulation of malathion in granular carbon for protection against insect attacks. All malathion treatments were applied at the standard dosage rate of 10.42 parts per million technical malathion.

The entomological phases of the studies were conducted at the U.S. Grain Marketing Research Center, administered by the Agricultural Research Service (ARS), U.S. Department of Agriculture (USDA), Manhattan, Kans. Edwin B. Dicke and Joseph L. Wilson assisted in the entomological phases. Malathion residue determinations were made by A. G. Quintana, E. Cooper, Jr., and E. Kroboth of the Chemical Unit at the Stored-Product Insects Research and Development Laboratory, also administered by ARS, USDA, Savannah, Ga. Gardona residues were determined by the Shell Chemical Co., Agricultural Chemicals Division, Princeton, N.J.

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Evaluating Gardona and Malathion To Protect Wheat In Small Bins Against Stored-Grain Insects

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SUMMARY

Low-volume (LV) spray and drip-on applications of malathion, an ultra-low-volume (ULV) application of Gardona, and a formulation of malathion in granular carbon were compared as protective treatments against insect attack to wheat stored in small bins for 12 months. Damaging infestations of mixed populations of stored-grain insects developed in all bins of the untreated check wheat during the first 4 months of storage from insects released in the storage room.

The LV malathion emulsion spray and the malathion granular carbon application gave excellent protection for 12 months. Malathion residues that were recovered from the different replicates of the LV spray application were fairly consistent for each aging period. The residue gradually declined from 4.5 to 1.5 parts per million (p/m) during the 12-month storage. More malathion residue was found in samples with the granular application, but greater variation in parts per million occurred between the different replicate lots.

Unsatisfactory residue patterns were found in many analyses made on wheat treated with the LV drip-on emulsion. Samples from three of the five bins showed deposits far below the desired amounts while one bin had an excess of residue. Protection against insect attack varied accordingly.

Gardona residues, which averaged 6.16 p/m 24 hours after treatment, decreased rapidly during the first 2 months of storage to an average of only 1.78 p/m. Sufficient residues remained, however, to protect the wheat against insect attack in the bins for 8 months.

BACKGROUND AND OBJECTIVES

The primary objectives of this study were (1) to determine the effectiveness of different formulations and methods of application of malathion and a chemical, Gardona, as protectants of Hard Winter wheat against insect attack and (2) to record the residues remaining on the wheat at selected intervals during 12 months' storage.

Generally, three phases of testing are completed in developing a protective treatment for stored grains: (1) Preliminary laboratory screening tests in glass jars; (2) intermediate-type, small-bin storage studies with the materials selected based on the results obtained during the laboratory studies; and (3) field-scale, large-volume experiments with selected dosages and materials that showed promise in the intermediate-type tests.

In an intermediate type, small-bin (5 ft^3) storage study with sorghum grain, malathion was applied in a concentrated form. It gave better protection against insect attack than that afforded by malathion applied in a diluted form as a water emulsion.[1]

Gardona applied at scalar dosages to wheat appeared promising. It, however, was not as effective as malathion as a grain protectant material against rice weevils *Sitophilus oryzae* (L.), red flour beetles *Tribolium castaneum* (Herbst), confused flour beetles *T. confusum* Jacquelin duVal, and lesser grain borers *Rhyzopertha dominica*

[1] La Hue, Delmon W. EVALUATION OF SEVERAL FORMULATIONS OF MALATHION AS A PROTECTANT OF GRAIN SORGHUM AGAINST INSECTS . . . IN SMALL BINS. U.S. Dept. Agr., Mktg. Res. Rept. 828, 19 pp., illus. 1969.

(F.), in extensive preliminary laboratory studies.[2]

Lemon[3] concluded that SD 8447 (Gardona) merited evaluation as a grain protectant. Studies indicated Gardona was more effective in topical applications than malathion against confused flour beetles, red flour beetles, lesser grain borers, and certain other insect pests of grain.

In the intermediate-type, small-bin study reported here, malathion was applied to wheat at a rate of 10.42 p/m as a low-volume (LV) emulsion spray, a LV drip-on, and as a 5-percent granular carbon formulation. Gardona was applied at 10.42 p/m as an ultra-low-volume (ULV) concentrate spray.

MATERIALS AND METHODS

The experiment was conducted with newly harvested, uncleaned Hard Winter wheat treated directly after combining. The LV water emulsion spray was formulated from premium grade 57-percent malathion emulsifiable concentrate and neutral distilled water. The emulsion, containing the standard dosage of 1 pint of the concentrate in 2 gallons of water, was applied by siphon through a Spraying Systems Co. ¼-inch JN atomizing nozzle block at 10 lb/in^2 air movement at the rate of 2 gallons emulsion per 1,000 bushels. The block was fitted with No. 2050 fluid and No. 70 air nozzles to deliver a round spray pattern.

The ULV application of Gardona emulsifiable concentrate was made at the rate of 2.5 pints per 1,000 bushels (10.42 p/m). It was applied with the ¼-inch JN atomizing nozzle block fitted with No. 1650 fluid and No. 64 air nozzles. Acetone was run through the block assembly immediately following the application to insure that all of the insecticide was removed from the apparatus and was deposited on the grain.

A fine-textured, granulated carbon, formulated by The Great Lakes Carbon Corp. to contain 5-percent malathion, was applied at the rate of 12.51 pounds per 1,000 bushels for a deposit of 10.42 p/m technical malathion. This material, a —20 +40 grind, the finest of five grinds formulated for laboratory screening studies, was selected for the intermediate-type storage studies following uniformity of application and adherence tests. The granular malathion was thoroughly mixed with the wheat by rotating in a barrel for 15 minutes.

The LV drip-on malathion emulsion was applied to the grain on the farm immediately following combine harvesting.[4] Two gallons of a water emulsion containing 1 pint of premium grade 57-percent malathion emulsifiable concentrate was applied to 1,000 bushels of wheat in droplets from a plastic container as the wheat was unloaded from the farm trucks and was loaded into the bins. An on-and-off needle valve assembly regulated the flow of the emulsion. The container was occasionally shaken by hand to prevent material separation in the emulsion. Four bushels from each of five farm-treated lots were placed in small, 5-cubic-foot bins for this treatment.

Five bins of untreated wheat were included as checks. The grain surfaces were leveled to provide equal exposure areas in all bins. Each bin represented a treatment replicate, and all treatments were replicated five times in a five by five block selective randomized arrangement.

The 25 bins were placed in five rows with five bins per row in a 13- by 18-foot heated room. A humidistat-controlled, water-evaporating cooling unit maintained a relative humidity of about 50 percent. Temperature conditions favored insect development throughout the 12 months of bin storage.

Major insect releases, each of about 6,000 rice weevils, 3,000 confused flour beetles, and 4,000 red flour beetles, were made in the storage room 14, 30, 75, 135, 180, and 260 days after the experiment was started. No lesser grain borers were released in the room but developing populations were seen in the infestation room during the last 8 months of storage. Jar cultures of flat grain beetles *Cryptolestes pusillus* (Schönherr) were maintained in the storage room for 8 months.

[2] LA HUE, D. W. GARDONA AS A PROTECTANT AGAINST INSECTS IN STORED WHEAT. J. Econ. Ent. 66: 485-490. 1973.

[3] LEMON, R. W. LABORATORY EVALUATIONS OF SOME ADDITIONAL ORGANOPHOSPHORUS INSECTICIDES AGAINST STORED-PRODUCT BEETLES. J. Stored-Prod. Res. 3: 283-287. 1967.

[4] WHITE, G. W. Unpublished data. 1967.

SAMPLING

At the beginning and end of the 12-month storage study, samples from the 4 bushels in each bin were submitted to the Inspection Branch, Grain Division, Agricultural Marketing Service, USDA, at Kansas City, Mo., for official grade determinations. Excess grain, collected during the bin surface leveling procedures, was utilized in all studies made immediately after treatment.

For subsequent samplings, the wheat was taken with a nonpartitioned grain probe at 4, 8, and 12 months after treatment. The probe was inserted vertically twice near the center and about 3 inches from the bin wall in each of the four quadrants. These samples, about 2,000 grams per bin, were held in sealed 1-gallon glass jars until they were used in the studies conducted soon after the samplings were completed.

The samples were sifted on a Rotomatic sifter, and the insects were counted for an estimation of the population in each bin. The fine dusts from the samples containing granular malathion were immediately separated from the screenings and returned to the parent sample. These samples were mixed for 15 minutes on a wheel mixer before determining test weights, damage to kernels, and moisture content.

All subsamples used in the toxicity, food preference, and repellency studies were held in a deep freeze at $-20°$ F for 168 hours before insect exposures to eliminate the possibility of an insect emergence because of a self-contained infestation. Before testing, these samples were held at 80° and 60 percent relative humidity for 48 hours following removal from the deep freeze to allow for moisture and temperature equation.

Four 200-gram subsamples from each bin sample were placed in 1-pint screen-covered glass jars for toxicity tests. Groups of about 50 adult insects —rice weevils, red flour beetles, confused flour beetles, and lesser grain borers—were placed in separate jars. Mortality counts were made 21 days later, and the live and dead insects were discarded. All fine dusts removed from the samples during the screenings made for the mortality counts were returned to the respective jars. After the mortality counts were made, the subsamples were held for the emergence of F_1 progeny. Following the F_1 progeny counts, all samples were retained for an additional time for a visual assessment of damage by the progeny.

As a direct test of the acceptance or avoidance of the wheat treated by the different formulations, about 250 rice weevils were released in multichoice food preference or selection chambers.[5] In each of these chambers, five ½-pint cardboard cartons, each filled with wheat from one of the four different treatments and from the untreated check, were exposed to the dispersal of about 250 rice weevils released in the center depression. The rice weevils were allowed 24 hours to enter and remain in the cartons of grain.

Repellency tests were conducted with replicated samples from all bins 24 hours and 4, 8, and 12 months after treatment. The treated grain was compared with untreated, uninfested source wheat (fig. 1). Five ½-pint cartons of treated wheat from a bin and five of untreated wheat were alternated in the apparatus. About 500 rice weevil adults, 14 days old, were liberated in the depressed release area located in the center of the chamber to scatter over the dispersal plane. The insects were given a 24-hour opportunity to choose from among the cartons of treated and untreated wheat. Following the dispersal period, the rice weevils were sifted from the wheat for counting.

The grain temperature in all bins was taken at bimonthly intervals by inserting a glass thermometer into the center of the grain mass. Samples for residue analysis were taken with the nonpartitioned grain trier.

As the individual bins were emptied at the end of the test, duplicate 1-gallon samples were progressively collected from top to bottom. These samples were passed over a 10-mesh screen to remove the insects, kernel bits, dusts, and frass. The screenings were sifted over a No. 18 sieve to separate the insect frass and other dusts from the insects and kernel bits. The frass and dusts were weighed to estimate the insect damage to the grain; this material was remixed with the sifted grain and was stored in covered 1-gallon glass jars. These samples were held for 42 days to observe insect development and emergence.

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[5] See reference in footnote 1, p. 1.

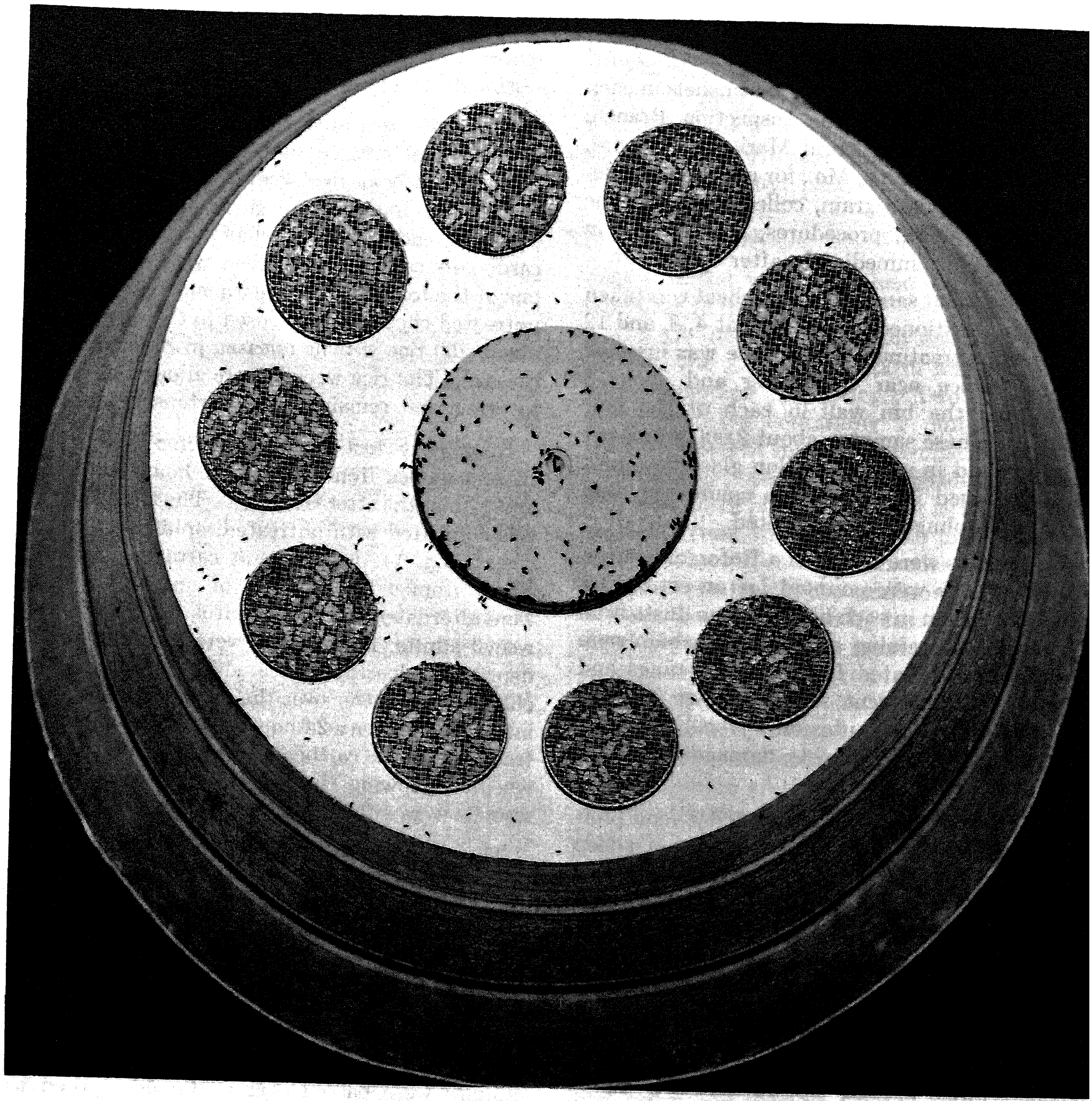

FIGURE 1.—Repellency test chamber showing dispersal of rice weevils BN-31490

RESULTS

Grain temperature and moisture

Slight elevations in grain temperature were first noted in bins of untreated wheat during the last part of the third month (table 1). Insect activity caused the temperature to rise in one of the bins with the malathion drip-on treatment after 5 months' storage, in three bins after 7 months, and in four bins after 9 months. Insects also caused the temperature to rise in two of the five bins with the Gardona treatment after 10 months. No temperature elevations from insect activity occurred in bins with the LV malathion spray or the 5-percent malathion granular carbon treatments.

TABLE 1.—*Average grain mass temperatures during 12 months' storage*

Treatment	Months of storage											
	1	2	3	4	5	6	7	8	9	10	11	12
	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
Gardona, ULV spray	75.0	68.6	69.6	70.8	63.8	60.3	62.6	65.3	68.8	70.6	85.7	83.8
Malathion:												
LV drip-on	75.0	69.0	70.0	71.2	67.0	63.9	66.0	68.6	74.9	80.0	91.0	89.6
LV spray	75.0	68.0	69.0	70.0	63.9	59.9	62.2	66.0	68.4	70.4	84.8	81.8
Granular	75.0	68.0	69.0	70.0	64.3	59.7	62.5	66.2	68.9	70.8	84.9	82.0
Untreated check	75.5	69.4	71.4	83.7	81.4	80.7	83.8	82.3	89.1	92.8	101.8	99.4
Room air[1]	77.2	67.8	68.2	70.4	64.2	59.6	63.0	66.4	68.0	72.2	85.3	82.0

[1] Averages of daily temperatures in testroom.

The source wheat contained about 12.2 percent moisture when the experiment was started, and it remained at that level for the greater part of the storage period. The treated lots remained near this level except for the winter months (8 months after treatment) when the gas-fired furnace used in heating the storage area was in constant operation (table 2).

Malathion residues

The results of the residue analyses are shown in table 3. The residues from the samples of wheat treated with the LV malathion spray were consistent, and gradually declined during 12 months' storage. Residues from wheat with the granular application were considerably greater than those recovered from wheat treated with the LV spray, and greater variation occurred between the replicated bin lots. Residues found on the five lots of wheat treated on the farm by the LV drip-on method varied considerably with three that had residues far below the deposit desired 1 month after treatment. One of the five bins had residues much higher than desired. These residue data indicate that erratic residual deposits may result from malathion emulsion applications made by the LV drip-on apparatus used in this test.

TABLE 2.—*Moisture content of wheat at given intervals during storage*

Treatment	Moisture content in samples taken[1]				
	Before treatment	After treatment			
		24 hours	4 months	8 months	12 months
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Gardona, ULV spray	12.34	12.11	11.82	10.51	11.71
Malathion:					
LV drip-on	12.30	11.98	11.82	10.66	12.14
LV spray	12.20	12.08	11.82	10.46	11.81
Granular	12.10	12.08	11.88	10.41	11.78
Untreated check	12.02	12.00	11.83	10.63	12.87

[1] Determined on a Steinlite RC 512 Moisture Tester.

TABLE 3.—*Malathion residues on Hard Winter Wheat at given intervals during storage*

Treatment and replication number	Months of storage							
	1	2	3	4	5	6	8	12
LV drip-on:	P/m	P/m	P/m	P/m	P/m	P/m	P/m	P/m
1	14.5	16.4	15.6	12.6	6.8	6.5	9.8	3.5
2	1.7	1.2	1.7	1.7	1.6	.9	1.7	.8
3	2.7	1.4	1.7	1.8	1.5	.9	2.0	.7
4	.5	.5	.6	.2	.3	.3	.2	.3
5	5.4	2.0	2.9	2.9	2.1	1.7	3.3	1.6
Average	5.0	4.3	4.5	3.8	2.5	2.4	3.4	1.3
LV spray:								
1	3.7	3.6	4.1	2.8	2.2	2.8	2.3	1.3
2	5.4	3.5	4.6	3.3	2.7	3.0	2.0	1.5
3	4.0	5.9	3.7	2.8	2.4	2.5	1.9	1.5
4	4.8	4.2	4.7	3.3	2.9	2.9	2.4	1.5
5	4.5	4.8	4.2	5.0	3.2	3.5	2.8	1.7
Average	4.5	4.4	4.3	3.4	2.7	2.9	2.3	1.5
Granular:								
1	16.0	16.1	10.1	13.5	5.5	5.4	3.8	1.5
2	8.6	12.1	6.9	3.7	4.7	3.9	2.6	1.5
3	4.8	4.6	3.5	3.7	3.2	6.1	2.2	2.0
4	4.9	8.5	7.9	5.9	5.0	5.3	3.4	2.4
5	9.6	14.6	21.6	12.9	13.5	15.3	8.9	7.8
Average	8.8	11.2	10.0	7.9	6.4	7.2	4.2	3.0

Gardona residues

Gardona residues averaged 6.16 p/m in samples taken 24 hours after treatment (table 4). A marked degradation of residues was indicated during the first 2 months of storage when an average of 1.78 p/m was recorded; thereafter, a

TABLE 4.—*Gardona residues on Hard Winter wheat at given intervals during storage*

Replication number	24 hours	2 months	4 months	6 months	8 months	12 months
	P/m	*P/m*	*P/m*	*P/m*	*P/m*	*P/m*
1	4.9	1.1	1.2	0.5	0.7	0.8
2	6.0	1.7	1.7	.5	.8	.8
3	6.7	1.5	1.6	.7	.8	.8
4	6.9	2.1	1.4	.5	.8	.8
5	6.3	2.5	1.8	.8	1.1	.8
Average	6.2	1.8	1.5	.6	.8	.8

more or less gradual decline was noted. The residue readings were consistent from bin to bin indicating that the procedure was an acceptable method of ULV application for small-bin, intermediate-type experiments.

Insect populations

The numbers of live adult insects recovered from the probe samples taken at specified intervals indicated the populations within the bins (table 5). After 4 months' storage, 803 live insects were found in the samples probed from the untreated bins; after 8 months, 9,337 live insects; and after 12 months, 38,708 live insects were recovered. During the first two sampling periods only 2 and 47 live insects, respectively, were recovered from samples taken from bins with the ULV Gardona application, but during the last 4 months of storage, the Gardona residues were not sufficient to prevent the development of relatively large populations.

The malathion LV spray and granular applications effectively controlled the insects during the first 8 months and greatly suppressed population development during the last 4 months of storage. The residues from the drip-on applications (table 3) were effective for 12 months in two of the bins, but large populations gradually developed in the other three bins.

Food selection studies

Competitive multichoice offerings of samples from the different bins to 14-day-old rice weevil adults showed that none of the treatments affected the acceptability of the wheat (table 6). These tests confirmed observations that the insects indicated no selectiveness in their movement into the bins following releases of insects in the storage room.

From 96.3 to 100 percent of the weevils released in the chambers entered the test cartons.

Repellency studies

None of the treatments induced repellency to 14-day-old rice weevil adults (table 7). From

TABLE 6.—*Response of rice weevils to insecticide-treated and untreated wheat in food selection tests*[1]

Treatment	Percent of weevils that entered samples after storage period of— 24 hours	4 months	8 months	12 months
	Percent	*Percent*	*Percent*	*Percent*
Gardona, ULV spray	21.06	23.19	19.31	16.09
Malathion:				
LV drip-on	22.38	20.16	19.43	26.44
LV spray	18.17	19.10	21.36	16.86
Granular	19.30	19.40	22.09	21.84
Untreated check	19.09	18.14	17.80	18.77

[1] Average of 10 replications.

TABLE 5.—*Live adult insects in probed samples of wheat taken during 12-months' storage*[1]

Treatment	Insects in samples: 4 months: Rice weevil	Flour beetle	Lesser grain borer	Other	Total	8 months: Rice weevil	Flour beetle	Lesser grain borer	Flat grain beetle	Other	Total	12 months: Rice weevil	Flour beetle	Lesser grain borer	Flat grain beetle	Other	Total
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Gardona, ULV spray	1	1	0	0	2	30	9	5	3	0	47	2311	898	2603	807	49	6668
Malathion:																	
LV drip-on	98	76	30	17	221	769	101	503	94	16	1483	7664	1209	13407	1202	218	23700
LV spray	4	12	1	1	18	17	22	9	16	1	65	803	671	987	504	16	2981
Granular	0	0	0	0	0	10	21	9	6	1	47	967	783	1191	463	44	3448
Untreated check	440	191	134	38	803	4480	653	3716	459	29	9337	8404	4671	16616	8901	116	38707

[1] Totals from 5 replications.

TABLE 7.—*Repellency of treated wheat to rice weevil adults*

Treatment	Repellency after interval of [1]— 24 hours	4 months	8 months	12 months
	Percent	*Percent*	*Percent*	*Percent*
Gardona, ULV spray ..	−2.0	−2.7	−4.3	10.81
Malathion:				
LV drip-on	3.2	19.5	−9.2	29.10
LV spray	−2.0	−9.2	5.9	−27.20
Granular	2.0	13.6	7.6	−15.80
Untreated check	−1.9	−4.6	5.1	−19.63

[1]Equation for repellency: $100 - (T \div \frac{U+T}{2} \times 100)$. U is the number of insects in the untreated wheat and T, the number in the treated wheat.

93.2 to 97.6 percent of the weevils released in the repellency chambers entered the test cartons.

Toxicity studies

Counts of live and dead rice weevil progeny were made 35 days after the mortality readings. In tests of Gardona-treated wheat, after 4 months' storage, complete kills of adult rice weevils were obtained, but some progeny emerged (table 8). Even though many of these progeny developed, good kills of rice weevils were still obtained 8 months after treatment. A complete loss of effectiveness was indicated in tests made after 12 months' storage.

Complete kills of adult rice weevils were obtained in wheat with malathion LV spray and granular formulations 8 months after treatment, although a definite loss in effectiveness of both applications was noted in tests conducted after 12 months. With the malathion LV drip-on treatment, complete kills of rice weevils were obtained for 12 months in samples from one bin and for 8 months in another bin; however, the residues were ineffective to wheat from the other three bins.

Malathion LV spray and granular applications effectively controlled the red flour beetle adults for 4 months and suppressed progeny development throughout the 12-month storage period (table 9). The malathion LV drip-on application was effective against adult red flour beetles for 8 months and suppressed progeny development for 12 months in samples from one bin, but little control was evident in the other four bins with this treatment after 4 months' storage. Gardona killed 88.69 percent of the adults after 4 months' storage and suppressed progeny development for 8 months.

Malathion LV spray and granular applications suppressed confused flour beetle progeny development throughout the 12-month storage period even though kills of adults were unsatisfactory in all exposures made after 4 months' storage (table 10). Progeny development was suppressed for 8 months by the Gardona application, but only 7.63 percent of the adults were killed at that time. In the malathion drip-on treated wheat, kills of adult confused flour beetles were very low throughout the tests in samples from three of the five bins; however, progeny development was completely suppressed in one bin for 12 months and for 8 months in the other.

The malathion LV spray and granular applications were effective in suppressing progeny development of lesser grain borers in tests conducted 8 months after treatment even though all adults were not killed in the toxicity test exposures (table 11). Gardona did not give the desired

TABLE 8.—*Adult rice weevil mortality after 21 days' exposure to insecticide-treated wheat and subsequent emergence of the F_1 progeny 56 days after infestation*[1]

Treatment	4 months: Mortality	4 months: Progeny Total	4 months: Progeny Dead	8 months: Mortality	8 months: Progeny Total	8 months: Progeny Dead	12 months: Mortality	12 months: Progeny Total	12 months: Progeny Dead
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Gardona, ULV spray	100.0	83.8	36.3	91.8	278.8	20.2	3.2	1362.0	0.2
Malathion:									
LV drip-on	79.1	489.8	15.7	76.5	495.2	13.7	39.1	935.0	4.7
LV spray	100.0	35.4	100.0	100.0	117.8	92.4	81.1	876.6	4.2
Granular	100.0	17.4	98.9	100.0	77.8	87.4	76.8	461.2	31.9
Untreated check	.2	1098.0	1.0	3.7	1360.6	.2	.7	1304.0	.2

Period between treatment and infestation of wheat: 4 months, 8 months, 12 months.

[1]Average of 5 replications.

TABLE 9.—*Adult red flour beetle mortality after 21 days' exposure to insecticide-treated wheat and subsequent emergence of the F_1 progeny 63 days after infestation*[1]

Treatment	Period between treatment and infestation of wheat								
	4 months			8 months			12 months		
	Mortality	Progeny		Mortality	Progeny		Mortality	Progeny	
		Total	Dead		Total	Dead		Total	Dead
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Gardona, ULV spray	88.7	1.0	80.0	22.3	0	—	1.2	43.2	3.7
Malathion:									
LV drip-on	59.4	4.8	12.5	31.4	21.0	1.0	6.5	67.8	1.2
LV spray	97.6	.6	100.0	62.2	0	—	9.4	1.8	44.4
Granular	100.0	0	—	88.2	0	—	25.8	.8	50.0
Untreated check	.7	[2]40.8	0	2.3	76.8	1.6	0	93.0	1.5

[1] Average of 5 replications.
[2] Counts made 56 days after infestation.

TABLE 10.—*Adult confused flour beetle mortality after 21 days' exposure to insecticide-treated wheat and subsequent emergence of the F_1 progeny 70 days after infestation*[1]

Treatment	Period between treatment and infestation of wheat								
	4 months			8 months			12 months		
	Mortality	Progeny		Mortality	Progeny		Mortality	Progeny	
		Total	Dead		Total	Dead		Total	Dead
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Gardona, ULV spray	84.0	0	—	7.6	0	—	0.4	57.0	1.1
Malathion:									
LV drip-on	39.9	10.0	20.0	14.6	15.8	6.3	7.3	57.6	1.7
LV spray	88.8	1.8	100.0	32.6	.4	50.0	12.0	1.0	0
Granular	95.3	0	—	65.7	0	—	35.8	1.2	0
Untreated check	.7	[2]45.6	0	3.1	88.6	1.1	0	97.0	1.0

[1] Average of 5 replications.
[2] Counts made 63 days after infestation.

TABLE 11.—*Adult lesser grain borer mortality after 21 days' exposure to insecticide-treated wheat and subsequent emergence of the F_1 progeny 63 days after infestation*[1]

Treatment	Period between treatment and infestation of wheat								
	4 months			8 months			12 months		
	Mortality	Progeny		Mortality	Progeny		Mortality	Progeny	
		Total	Dead		Total	Dead		Total	Dead
	Percent	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*
Gardona, ULV spray	82.7	26.8	6.0	61.8	57.8	2.8	0	417.4	0.6
Malathion:									
LV drip-on	55.1	25.8	3.1	51.4	67.6	1.5	5.2	366.4	1.9
LV spray	90.2	1.2	100.0	67.2	2.0	20.0	13.9	76.8	.5
Granular	99.6	1.0	100.0	90.6	1.8	22.2	19.9	45.6	.9
Untreated check	0	421.6	.3	.7	355.0	.6	0	487.6	.5

[1] Average of 5 replications.

protection after 4 months' storage. Kills of lesser grain borer adults were negligible in samples from one of the five bins of wheat treated by the malathion drip-on method throughout the test, and in two other bins after 4 months' storage; however, the residues suppressed progeny development in the two remaining bins for 8 months and in one of these for 12 months.

Insect emergence

The emergence of insects from the 1-gallon samples taken progressively as the bins were emptied at the end of the test showed the extent of the self-contained infestations that had become established in the wheat during the 12-month storage period (table 12). All bins were infested. The fewest insects emerged from the samples treated with the LV spray and granular malathion. Rice weevil infestations were firmly established in all bins with these treatments but relatively few lesser grain borers and flour beetles were found. Large numbers of insects emerged in the samples from the bins of wheat treated with Gardona and from four of the five bins with the malathion LV drip-on treatment.

TABLE 12.—*Emergence of live adult insects from samples of insecticide-treated wheat after 12 months' storage*[1]

Treatment	Rice weevils	Flour beetles	Lesser grain borers	Flat grain beetles	Others	Total
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
Gardona, ULV spray	2,280.0	54.0	1,688.0	505.0	8.0	4,535.0
Malathion:						
LV drip-on	2,106.2	396.4	2,119.4	833.6	3.8	5,459.4
LV spray	986.0	4.0	82.8	26.6	1.2	1,100.6
Granular	1,616.2	24.0	62.0	190.6	1.0	1,838.0
Untreated check	204.6	522.2	4,315.0	1,386.2	20.4	6,448.4

[1] Gallon samples held for 54 days following collection for emergence of insects (average of 5 replications).

Insect damage

Assessments of insect damage to the wheat recorded after 12 months' storage included the amounts of insect frass in samples, losses in test weight, percentages of kernels damaged by insects, and kernel weight losses. Weights of fine dusts, primarily insect frass, sifted from the samples taken as the bins were emptied at the end of the storage period, indicated the damage from insect feeding during storage (table 13).

The small amounts of dusts recovered from the bins with malathion LV spray and granular treatments suggested a relatively slight amount of insect damage to the wheat kernels. The amounts recovered from wheat treated with Gardona, although nearly four times as much as from the malathion LV spray and granular treatments,

TABLE 13.—*Weight of insect frass per gallon sample of wheat 12 months after treatment*

Treatment	Average[1]	Range
	Grams	*Grams*
Gardona, ULV spray	16.03	6.11- 32.10
Malathion:		
LV drip-on	52.87	4.87-187.26
LV spray	4.09	2.07- 7.13
Granular	4.64	2.53- 7.04
Untreated check	264.52	105.75-458.31

[1] Average of 10 samples from each treatment.

indicated that relatively little kernel damage was inflicted during the 12-month storage period compared with the untreated check. Small amounts of dusts were recovered from one bin with the malathion LV drip-on treatment but recoveries from the other four bins were considerable.

The changes in the test weight of the wheat are shown in table 14. Little weight loss occurred in wheat with the malathion LV spray and granular treatments. Wheat treated with Gardona lost 1.21 pounds per bushel compared with a loss of 15.55 pounds in the untreated wheat. Wheat with the malathion LV drip-on treatment lost 5.12 pounds per bushel.

Replicated samples of kernels from each bin didn't include many of the heavily damaged kernels, especially those that had extensive internal feeding and that were often broken up and passed through the screen during the removal of insects and dusts by a screening process. Consequently, losses to heavily damaged kernels are sometimes not recorded by this method of determining percent of kernels damaged and kernel weight loss. The samples were examined at the end of the 12 months' storage to determine the percentage of kernels damaged by insects and to

TABLE 14.—*Test* [illegible] *given intervals* [illegible]

Gardona, ULV spray	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Malathion:					
LV drip-on	58.15	57.90	56.40	53.03	5.12
LV spray	58.34	58.38	58.37	58.08	.26
Granular	58.26	58.28	58.08	58.00	.26
Untreated check	58.20	57.35	53.35	42.67	15.55

TABLE 15.—*Kernel damage and calculated weight loss of wheat after 12 months' storage*[1]

Treatment	Kernels damaged	Kernel weight loss
	Percent	*Percent*
Gardona, ULV spray . .	11.28	3.97
Malathion:		
LV drip-on	31.00	13.34
LV spray	8.60	2.38
Granular	5.96	1.89
Untreated check	95.20	44.34

[1] Average of 5 replications (1,000 kernels each).

calculate the kernel weight loss from feeding of the insects.

In the untreated bins, damage was heavy with over 95 percent of the kernels showing insect feeding (table 15). In comparison, damage was relatively light in the wheat with the malathion LV spray and granular treatments that had 8.60 and 5.96 percent of the kernels damaged with calculated kernel weight losses of 2.38 and 1.89 percent, respectively.

Damage to the kernels from the Gardona treatment averaged 11.28 percent with a calculated kernel weight loss of 3.97 percent. Wheat kernels treated by the malathion LV drip-on method was heavily damaged in three of the five lots under test; however, practically no damage occurred to the wheat in the bin with the high malathion residue. Damage in the remaining bin was comparable with damage in the bins with the LV spray and granular treatments.

Progeny damage

Estimates of the extent of damage caused by the progeny of the insects exposed to the treated grain in the toxicity tests completely substantiated all other findings (tables 16 through 19). Data concerning the damage caused by rice weevil progeny shown in table 16 confirm the mortalities and F_1 progeny development shown in table 8.

The residues from the malathion LV spray and granular applications were sufficient to prevent extensive population development and damage by rice weevils for 8 months and to suppress damage during the next 4 months. Gardona residues did not completely protect the wheat from becoming infested with rice weevils 4 months after treatment, but progeny development was suppressed when compared with the untreated wheat. Damage to wheat with the malathion LV drip-on application was considerable in the three bins with the lowest residue deposits.

The malathion LV spray and granular applications were effective in preventing the development of damaging populations of red and confused flour beetles (tables 17 and 18). Slight damage by these two insect species to wheat treated with the Gardona ULV spray occurred in samples taken after 12 months' storage. Drip-on treated wheat had noticeable damage after 4 months.

The malathion residues from the LV spray

TABLE 16.—*Visible damage by rice weevil progeny, after toxicity tests with samples of wheat collected at specified intervals during storage*

Treatment	Damage observed 120 days after storage of—[1] 4 months	8 months	12 months
	Rating	*Rating*	*Rating*
Gardona, ULV spray . .	1.2	2.6	4.8
Malathion:			
LV drip-on	2.6	3.2	4.2
LV spray	0	.8	3.4
Granular	0	.6	2.6
Untreated check	5.0	4.8	5.0

[1] Damage rating codes: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amounts of insect frass and spoilage of grain.

TABLE 17.—*Visible damage by red flour beetle progeny after toxicity tests with samples of wheat collected at specified intervals during storage*

Treatment	Damage observed 150 days after storage of—[1] 4 months	8 months	12 months
	Rating	*Rating*	*Rating*
Gardona, ULV spray . .	0	0	1.2
Malathion:			
LV drip-on	.2	.6	1.2
LV spray	0	0	0
Granular	0	0	0
Untreated check	2.2	2.8	2.8

[1] Damage rating codes: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amounts of insect frass.

TABLE 18.—*Visible damage by confused flour beetle progeny after toxicity tests with samples of wheat collected at specified intervals during storage*

Treatment	Damage observed 150 days after storage of—[1] 4 months	8 months	12 months
	Rating	*Rating*	*Rating*
Gardona, ULV spray	0	0	1.0
Malathion:			
LV drip-on	.2	.4	1.2
LV spray	0	0	0
Granular	0	0	0
Untreated check	2.2	2.2	2.6

[1]Damage rating codes: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amounts of insect frass.

application was somewhat less effective in preventing lesser grain borer progeny damage than the residues from the granular treatment (table 19). Both treatments greatly suppressed the development of large populations. Residues from the Gardona ULV applications suppressed lesser grain borer progeny development in tests made after 4 months' storage, but thereafter large damaging populations were noted in all samples. Lesser grain borer damage to wheat with the LV drip-on application of malathion was heavy in samples from three of the five bins after 8 months' storage; however, progeny did not develop in the bin with 3.5 p/m malathion deposit after 12 months' storage.

TABLE 19.—*Visible damage by lesser grain borer progeny after toxicity tests with samples of wheat collected at specified intervals during storage*

Treatment	Damage observed 120 days after storage of—[1] 4 months	8 months	12 months
	Rating	*Rating*	*Rating*
Gardona, ULV spray	2.6	4.4	5.0
Malathion:			
LV drip-on	1.6	2.6	3.8
LV spray	.2	.8	3.0
Granular	0	.2	2.2
Untreated check	5.0	5.0	5.0

[1]Damage rating codes: 0 = no visible infestation; 1 = slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4 = ascending numbers of insects and corresponding amount of insect frass; 5 = large infestation with great amounts of insect frass and destruction of grain.

TABLE 20.—*Commercial grade factors determined on the wheat immediately after treatment and after 12 months' storage*

Treatment and grading interval	Test weight	Moisture	Foreign material	Damaged kernels	Shrunken and broken kernels	Total defects	Samples with live insects	Insect damage	Odor	Dockage	Commercial grade Hard Winter wheat
	Pounds	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*		*Percent*	*Description*
Gardona, ULV spray:											
After treatment	59.3	12.5	0.1	1.0	2.3	3.4	0	0	None	0.7	No. 2 HW.
After 12 months	57.5	13.2	0	4.0	1.4	5.4	5	4.0	None	.2	No. 3 DHW.[1]
Malathion:											
LV drip-on:											
After treatment	58.5	12.5	.1	1.0	1.9	3.0	0	0	None	.5	No. 2 HW.
After 12 months	57.2	13.1	.1	[2]3.3	1.4	[2]5.0	4	[2]2.7	Sour[3]	[2].4	No. 3 DHW.[1 4]
LV spray:											
After treatment	59.5	12.5	.1	1.0	2.3	3.4	0	0	None	.7	No. 2 HW.
After 12 months	58.5	12.8	.1	2.0	1.6	3.7	0	1.0	None	.2	No. 2 DHW.
Granular:											
After treatment	58.7	12.5	.2	1.0	2.0	3.2	0	0	None	.7	No. 2 HW.
After 12 months	58.0	13.0	.1	2.5	1.6	4.2	0	2.0	None	.1	No. 2 DHW.
Untreated check:											
After binning	58.7	12.4	.1	.8	2.9	3.8	0	0	None	.4	No. 2 HW.
After 12 months	42.8	12.8	.2	60.0	1.0	61.2	5	58.0	Sour	15.0	Sample DHW.[1]

[1]Weevily.
[2]Average of 4 bins only, other bin very heavily damaged.
[3]No odor from 2 of the 5 bins.
[4]2 bins graded No. 3 DHW, 2 bins graded Sample DHW, 1 bin graded No. 2 DHW.

Commercial grade

The source wheat was graded as No. 2, Hard Winter (HW) at the beginning of the test. None of the treatments affected the grade (table 20). After 12 months' storage, the heavily damaged, untreated check which graded Sample Grade, Dark Hard Winter (DHW), Weevily, had 61.2 percent total defects.

Wheat from the malathion LV spray and granular treatments graded No. 2, Dark Hard Winter with 3.7 and 4.2 percent total defects, respectively. Wheat with the Gardona application graded No. 3, Dark Hard Winter, Weevily, with 5.4 percent total defects. Of the five bin sample lots with the malathion LV drip-on treatment, two lots were sample grade DHW-weevily, two graded No. 3 DHW-weevily, and the other lot graded No. 2 DHW.

CONCLUSIONS

Objective assessments were made of the protection provided by three formulations of malathion and one formulation of Gardona applied to wheat at the rate of 10.42 p/m active ingredient. All bin lots were given equal opportunity for infestation by mixed populations of stored-grain insects. Results obtained during the 12-month study were remarkably consistent between the replications of the treatments made at the storage site, but many variations were found in the results from the grain taken from the farm-treated lots (LV drip-on malathion treatment). There was a good correlation between the results shown by the different methods of evaluation of the effectiveness of the different treatments. The following conclusions were drawn from the results of the study:

1. Malathion applied as an LV emulsion spray at the rate of 1 pint of 57-percent premium-grade emulsifiable concentrate in 2 gallons of water per 1,000 bushels afforded excellent protection to Hard Winter wheat for 12 months. During this time the wheat was exposed to heavy and continuous attacks by mixed populations of stored-grain insects.
2. The residues from the malathion LV spray treatment gradually degraded in a consistent pattern during the 12-month storage period.
3. Malathion applied as a 5-percent granular formulation of carbon afforded protection equal to the malathion LV spray.
4. The malathion residues from the granular application exceeded those obtained with the LV spray; however, greater variations were found between comparable samples with the granular treatment.
5. Gardona applied as a ULV spray gave some protection from damage for about 8 months.
6. A rapid loss of the Gardona residues occurred during the first 2 months of storage; thereafter, a more or less gradual and consistent degradation pattern was recorded.
7. None of the treatments rendered the wheat distinctly repellent nor attractive to rice weevils.

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